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ABSTRACT

The authors describe investigations of the effect of plastic deformation on the properties of TiC, ZrC, TiB_2, and $MoSi_2$. The tests were carried out by the roentgenographic method and microhardness measurements.

Several theoretical and experimental investigations have been made to date /81*
[1 - 3] concerning problems related to reversion and recrystallization in refractory compounds after plastic deformation. However, in view of the complexity of the mechanisms of plastic deformation there is still no sufficient clarity in the understanding of their nature.

This report describes the results of experiments made in order to determine the effect of surface cold hardening on the properties of the refractory compounds TiC, ZrC, TiB_2, and $MoSi_2$. The investigations were performed on cylindrical specimens produced by the powder metallurgy method using high-temperature pressing. The starting materials were the powders whose chemical compositions are given in Table 1. Specimens with the lowest porosity (2 - 3%) were selected for the investigations.

TABLE 1

Chemical composition of refractory compounds, %

Compound	Metal	Nonmetal			Impurities
		General	Bound	Free	
TiC	80,2	18,8	0,04	—	—
ZrC	87,9	11,9	—	0,91	Fe—0,3
TiB_2	69,2	28,9	—	—	C—0,55
$MoSi_2$	63,5	34,0	—	—	C_{above}-0.35 C_{vol} - 0.2 Fe - 0.35

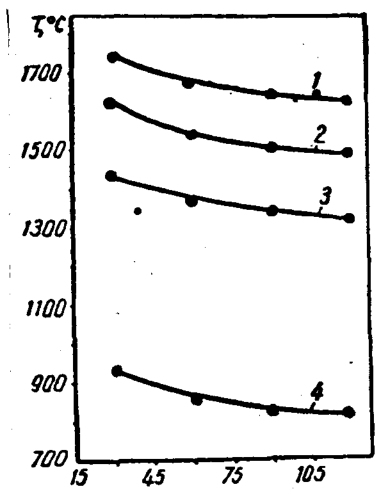
* Numbers given in the margin indicate pagination in original foreign text.

The surface cold hardening was achieved by polishing the specimens on a ZG-71 plane-grinding machine tool with K316SM1K and ASO 16-B1-50 disks using the following procedure: V_{cr} = 28 m/sec, V_{st} = 10 m/min, V_{pop} = 0.6 mm/double stroke, and polishing depth 0.03 mm.

The roentgenograms from the polished sections were taken in a cylindrical chamber 53.7 mm in diameter on Cu-K_α - radiation. The section was situated at an angle of 20 - 25° to the incident beam of x-rays In order to attenuate the fog from the secondary characteristic radiation, two films were installed in the chamber, the second of which was used in the work. Soft radiation was selected for the experiment so as to prevent the penetration of rays to a depth exceeding the thickness of the hardened layer.

The microhardness was measured on polished sections by a PMT-3 instrument at a load of 50 g (Table 2). The measurements show that the surface cold hardening of the specimens leads to an increase in the microhardness of the compounds examined and to heavy diffusion of the x-ray diffraction lines. The degree of line diffusion of the roentgenograms increases with a decrease in the alloy porosity. The values of the temperatures of recrystallization of the compounds investigated were determined from the /82 appearance of the first point pricks on the roentgenogram lines (Table 2).

The figure shows graphs of the variation of recrystallization temperature with the duration of the isothermal process during annealing. As follows from the data in Table 2, the relative recrystallization temperature T_r/T_{melt} for borides and carbides is approximately identical, and for silicides it is somewhat lower, however, overall this ratio is equal to about 0.5, whereas for metals it is 0.3--0.4 [4].



Annealing time, min

Temperature of start of recrystallization of refractory compounds at different times: 1-ZrC, 2-TiC, 3-TiB_2 4-$MoSi_2$.

Apparently, this fact can be attributed to the specific features of the structural transformations occurring in the refractory compounds during deformation, compared to the more plastic metals and alloys, as well as to the higher bonding energy in refractory compounds as compared to pure metals.

An increase in the relative recrystallization temperature of refractory compounds as compared to metals may also be compared with a decrease in metal-nonmetal compounds of the weight of the nonlocalized portion of valent electrons of metal atoms [5]. For instance, in the case of titanium carbide a portion of the nonlocalized electrons of titanium atoms passes into the localized state, participating in the formation of sp^3-configurations of carbon atom bonds [6]. The same is observed in the case of zirconium carbide, titanium boride, and molybdenum silicide, moreover, in the case case the ratio T_r/T_{melt} is the lowest and the closest to that of metallic molybdenum. In the last case, already in the metal state the statistical weight of the nonlocalized electrons is relatively low, and its further decrease during the formation of $MoSi_2$ is insignificant, since sp^3-configurations of silicon atoms are formed mainly due to the electron exchange between silicon atoms in the $MoSi_2$ lattice.

TABLE 2

Some characteristics of recrystallization processes of refractory compounds

Compound	Microhardness in cold hardened state, dan/mm^2	Microhardness in recrystallized state, dan/mm^2	T_r, °K	T_{melt}, °K	T_r/T_{melt}
TiC	2520±100	2310±125	1820	3420	0,53
ZrC	2470±100	2050± 50	1950	3803	0,51
TiB_2	2400±100	2380	1650	3253	0,51
$MoSi_2$	1060± 70	739± 30	1120	2303	0,48

A decrease in the weight of the nonlocalized portion of the valent electrons during the formation of transition with nontransition metal compounds restricts the possibilities of the s $\rightleftarrows$ d-exchange and induces an increase in the energy required for the excitation of the stable configurations formed by the localized portion of the valent electrons, which is precisely the factor causing the increase in the ratio T_r/T_{melt}.

REFERENCES /83

1. Gorelik, S. S., V. P. Yelyutin, Ye. I. Mozzhukhin, U. S. Urazaliyev, and V. F. Funke: X-ray Investigation of the Recrystallization Processes of Titanium, Zirconium, and Molybdenum Borides, and Titanium and Tungsten Carbides, Izv. vyssh. uch. zav., No. 4, Tsvetnaya Metallurgiya, 1962.
2. Grozin, B. D., V. M. Bakul', and V. M. Pelepelin: Prikladnaya Mekhanika, vol. 9, No. 1, 1963.
3. Golovinskiy, T. M. and V. M. Pelepelin: DAN UkrSSR, No. 10, 1963.
4. Bochvar, A. A.: Metallovedeniye, Oborongiz, Moscow, 1956.
5. Samsonov, G. V.: Ukr. khim. zh., vol. 31, p. 1233, 1965.
6. Arbuzov, M. P. and B. V. Khayenko: Poroshkovaya Metallurgiya, No. 4, p. 74, 1966.

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